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5            TITLE OF THE INVENTION

Process for Treating Industrial and Municipal  
Waste Water Highly Loaded with Ammonium

10           BRIEF SUMMARY OF THE INVENTION

15           The invention concerns a process for treating  
industrial and municipal waste waters highly loaded with  
ammonium. In accordance with the invention "ammonium" is  
understood as meaning both ammonium compounds as well as  
ammonia.

BACKGROUND OF THE INVENTION

20           Waste water loaded with ammonium, including highly  
loaded industrial waste water, can be purified in different  
ways. In the case of physical purification, the pH value is  
increased by the addition of lye, whereupon ammonia is  
removed by stripping with steam or with a gas and recovered  
25           by condensation. The profit from the recovered ammonia is  
very small in comparison with the high investment costs,  
and, in addition, waste waters can only be purified if they  
contain less than 100 mg  $\text{NH}_4$  - nitrogen ( $\text{NH}_4\text{-N}$ ) per liter in  
this way.

30           A chemical process for removal is based on the  
precipitation of magnesium ammonium phosphate. In this case  
magnesium salts and phosphates are added to the waste water,  
magnesium ammonium phosphate precipitates out at a specific  
35           pH value. The magnesium ammonium phosphate can be  
reprocessed by heating, producing magnesium hydrogen  
phosphate and ammonia, which can be removed by stripping.  
The magnesium hydrogen phosphate then can be added to the

5 waste water again as a precipitation agent. However, this process is very cost-intensive.

10 A further, more economical, biological process includes treating of the waste water with nitrifying microorganisms (nitric bacteria), the nitric bacteria being colonized on a solid carrier bed. The waste water is aerated, the nitric bacteria oxidizes the ammonium nitrogen to nitrite (Nitrosomonas) or to nitrate (Nitrobacter).

15 Formerly the solid carrier bed for this process in general, contained lava, while more recently, in general, plastic bars, balls, or fibers have been used. These materials create a colonization surface for the nitric bacteria.

20 A three-stage fluidized bed reactor, in which the biomass is colonized on a carrier substance (basalt), is presented in article No. 20 by J. Mihopoulos, "Cost-reducing Strategies for Water Treatment Plants: Separate Turbid Water Treatment" in the book "Sticksoffrückbelastung - Stand der Technik 1996/1997 - zukünftige Entwicklungen" ("Nitrogen reloading - State of the Art 1996/1997 - Future Developments") by J. St. Kollbach and M. Grömping, TK-Verlag Karl Thomé-Kozmiensky. This substance is held in suspension with recirculation. However, the carrier substance is fairly large-grained. In addition, its specific surface is below 10 m<sup>2</sup>/g. If the aeration stops, the carrier substance is precipitated, thus leading to blockage and death of the biofilm.

35 A process for nitrogen removal in water treatment

5 plants with a biological treatment stage, partial flows of  
the sludge treatment highly loaded with ammonium being used  
for growing nitric bacteria, is known from "Korrespondenz  
Abwasser", 12, 1994, p. 2261-2268. The active biomass  
10 obtained is used for promoting the nitrification in the  
subsequent purification stages. The use of nitric bacteria  
in the presence of aluminum and iron hydroxides is supposed  
to lead to a significant elimination of nitrogen in the  
treated waste water during the nitrification phase. Also,  
15 a considerable amount (67%) of the nitrogen loading already  
should be removed from the partial flows used for growing  
the nitric bacteria. In addition, the metal hydroxides  
loaded with nitric bacteria are removed with the sludge and  
can lead to environmental pollution as they easily release  
the corresponding trivalent cations.

#### 20 DETAILED DESCRIPTION OF THE INVENTION

The invention is based on the problem of treating  
industrial and municipal waste waters highly loaded with  
25 ammonium with the use of carrier substances, which make  
proper operation of the nitric bacteria possible with low  
investment and operating costs and largely prevent release  
of multivalent cations from the separated sludge.

30 Thus, one object of the invention concerns a process  
for treating industrial and municipal waste water highly  
loaded with ammonium in the waste water field by treating  
the waste waters with nitrifying microorganisms (nitric  
bacteria) in the presence of a suspended carrier substance,  
35 which is characterized by the fact that a silicate carrier  
substance with a specific surface area of  $> 20$  preferably  $>$

5        50 m<sup>2</sup>/g, is added to the waste waters and suspended therein,  
and the nitrifying waste water are optionally subjected to  
a denitrification with denitrifying microorganism  
(denitrifying bacteria).

10        The specific surface area is determined according to  
the BET method (one-point method with nitrogen according to  
DIN 66 131).

15        Preferably a natural silicate carrier substance with a  
particle size within 95% by weight < 150  $\mu$ m is used. In  
this way it is assured that the carrier substance also  
remains in suspension without expensive stirring devices.  
Natural silicate carrier substances, as opposed to synthetic  
20        carrier substances, are less inclined to release hazardous  
substances as they have been subjected to a natural leaching  
process over geological time. Thus they are more  
environmentally compatible than synthetic silicate carrier  
substances.

25        The silicate carrier substance in accordance with the  
invention offers a high colonization surface for the nitric  
bacteria. The high colonization surface makes it possible  
to treat waste water with high NH<sub>4</sub> concentrations, which can  
no longer be treated according to the known biological  
30        process. Preferably industrial waste water with an NH<sub>4</sub>-N  
content of about 200 to 2000 mg/liter, in particular with  
about 400 to 1600 mg/liter, is used.

35        The silicate carrier substance in general is used in  
amounts of about 5 to 50 g/liter. Also it is important  
that the specific weight of the carrier substances is over

5        1.5 g/cm<sup>3</sup>, so that the carrier substance does not float during aeration.

10        Preferably the silicate carrier substance has a surface pH value of about 6 - 9. This is determined by stirring a 10% by weight suspension of the silicate carrier substance in water for 15 minutes. The pH value is determined in the filtered solution by means of a glass electrode. Surprisingly it was found that a silicate carrier substance with a surface pH value outside of the indicated range has  
15        a low colonization density for the nitric bacteria, and that the colonization density also is not increased significantly if a pH value within the indicated range is set by the addition of acid or lye in the suspension of the silicate carrier substance.

20        Preferably the silicate carrier substance has a cation exchange capacity (IEC) of around 40 to 100 meq./100g, in particular 50 to 80 meq./100g. The cation exchange capacity is determined as follows:

25        The dried silicate carrier substance is reacted with a large excess of aqueous NH<sub>4</sub>Cl solution. After a standing time of 16 hours at room temperature it is filtered, the filter cake is washed, dried, and ground, and the NH<sub>4</sub> content  
30        in the carrier substance is determined according to the Kjeldahl method.

35        In addition, the silicate carrier substance preferably also is hydrophilic, that is, it should have a swelling volume of around 5 to 80 ml/2g, preferably of around 10 to 20 ml/2g. The swelling volume is determined as follows:

5           A calibrated 100 ml measuring cylinder is filled with  
100 ml of distilled water. 2.0 g of the substance to be  
measured are added slowly to the water surface in portions  
of 0.1 to 0.2 g. After the material sinks, the next portion  
is added. After the end of the addition one waits for one  
10 hour and then reads the volume of the swollen substance in  
ml/2g.

Because of the relatively small particle size and the  
swelling capacity it is assured that the carrier substance  
15 remains suspended homogeneously. If the mixture of waste  
water and silicate carrier substance tends to foam,  
antifoaming agent can be added.

Preferably clay minerals, in particular smectitic clay  
20 minerals, such as bentonite, vermiculite, chlorite,  
beidellite, hectorite, nontronite, and illite, are used as  
the silicate carrier substances. Bentonite (main mineral  
montmorillonite), which in addition to its function as a  
colonization surface also adsorbs ammonia and  $\text{NH}_4^+$  (in the  
25 latter case on the basis of the ion exchange capacity), is  
particularly preferred as the smectitic clay material.

Other usable silicate carrier substances are, among  
others, kaolin and serpentine minerals (such as kaolinite,  
30 dickite, nacrite, halloysite, antigorite), palygorskite,  
sepiolite, pyrophyllite, talcum, and zeolites.

The silicate carrier substance can be used in amounts  
of around 10 to 30 g/liter, preferably 15 g/liter. When  
35 less than 10 g/liter is used, not all of the  $\text{NH}_4$  nitrogen is  
decomposed. On the other hand, when of more than 30 g/liter

5 is utilized, no significant advantage can be determined any longer.

10 According to a modification of the aforesaid process, the object of the invention is achieved by using a carbon-containing material instead of the silicate carrier substance. Here also the optimal growth and proper operation of the nitric bacteria is ensured by providing of a suitable surface with a suitable surface pH value between 6 and 9.

15 The surface pH value preferably amounts to 6.5 to 8, and, if the material does not have this surface pH value originally, can be maintained, for example, by bringing an initially basic carbon-containing material in contact with an acid waste water.

20 In particular, active charcoal, lignite, coke, coke dust, anthracite, graphite, and/or carbon black are used as carbon-containing material. The materials preferably used all have a high specific surface area of  $> 20 \text{ m}^2/\text{g}$ , preferably from 30 to 50  $\text{m}^2/\text{g}$ . It is assumed that the large specific surface area has a positive effect on the growth and the proper operation of the nitric bacteria, in particular as a result of adsorption or desorption of specific metabolic products.

30 Preferably a carbon-containing material with a particle size wherein 95 % by weight  $< 400 \mu\text{m}$  is used. This range is somewhat greater than that in the case of using silicate carrier material, which is made possible by the fact that the carbon-containing materials are specifically lighter

5        that silicate carrier materials and therefore do not precipitate as rapidly. Usually carbon blacks have a particle size of 5 to 500 nm. The particle sizes of graphite and anthracite also lie in the nanometer range.

10        The carbon-containing carrier substance can be used in amounts of about 10 to 30 g/l, preferably 15 g/l. In the case of less than 10 g/l not all of the  $\text{NH}_4$  nitrogen is decomposed. On the other hand, in the case of more than 30 g/l no significant advantage can be determined.

15        It is advantageous that in the case of the use of the above-mentioned carbon-containing materials, no ash residues are formed at the time of burning the sewage sludge originating from the waste water treatment.

20        As mentioned above, a surface pH value of the carbon-containing carrier materials of 6 to 9, in particular 6 to 8.5 is preferred. In the case of using anthracite and/or graphite, which are pH-neutral, therefore no treatment has  
25        to be made in order to set the desired surface pH value. Of course, activated charcoal and lignite coke as well as coal dust are basic, and therefore are brought to the desired surface pH value by (pre-) treatment with acid. This can  
30        take place either by the addition of acid or acid solutions, or by pretreatment with an acid waster water.

35        The process in accordance with the invention is carried out with ammonia and ammonium-containing industrial and municipal waste waters. Therefore the process in accordance with the invention is not used within the framework of a normal biological purification stage; rather it is a



5 decentralized process for treating highly loaded waste waters.

10 Preferably partial flows from the sludge treatment and/or supernatant water (turbid water) from the sludge digestion and/or waste dump leakage water are used. The pH value drops as a result of the formation of nitrous acid or nitric acid, and the reaction comes to a stop. Therefore preferably the pH value is adjusted to about 6.5 to 8.5, in particular to about 6.8 to 7.2, at the time of the nitrification as a result of the addition of alkali. If no pH regulation is carried out, the nitrification efficiency is only about 40 to 60%. No reaction takes place any more below a pH value of 5.9. The nitrification efficiency is increased to over 90% by means of the addition of alkali. 15 In the case of a pH value of more than 9 the reaction also comes to a stop. 20

25 In order to achieve a rapid colonization of the carrier substance with the nitric bacteria, a suspension of the carrier substances preliminarily impregnated with the nitric bacteria is added to the waste waters, bacteria which oxidize the ammonia to nitrite preferably being used as the nitric bacteria. To a smaller degree microorganisms which oxidize the ammonia to nitrate also are used.

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By means of the process in accordance with the invention a nitrogen reloading can be avoided after the final denitrification with denitrifying microorganisms (denitrifying bacteria).

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The denitrification takes place under aerobic

5 conditions, preferably by supplying an oxygen-containing gas to the waste water. In general the oxygen concentration should amount to at least 2 mg/liter. Below this concentration the nitrification efficiency decreases.

10 The nitrified waste water cannot be introduced into the main canal directly because of the high nitrite content. Therefore in general it is necessary to add a denitrification at the outlet side, which can take place in an existing plant. The nitric bacteria absorb the oxygen  
15 from the waste waters, until the latter becomes anoxic; then it absorbs the oxygen from the nitrite, or from the nitrate, elementary nitrogen being released.

It was found that the nitrification can be optimized,  
20 if it carried out with a volumetric loading of about 0,5 to 2.5, preferably 1.9 to 1.5 kg  $\text{NH}_4\text{-N}/\text{m}^3$  waste water per day. The process also can be carried out in the case of somewhat smaller volumetric loads, if, for example, the  $\text{NH}_4\text{-N}$  content decreases in a sequence of operating variations.

25 This high volumetric loading makes it possible to carry out the process in a relatively small activation basin, by means of which the process can be fundamentally distinguished from the processes which are used in a normal  
30 biological purification stage.

Further, it has been found that in the case of waste water with a high organic carbon load, specified as chemical oxygen demand (COD), the carbon load decreases before the  
35 nitrification stage to about 300 to 1000, preferably to about 300 to 500 mg/liter. In the case of a high carbon

5 load, the growth of the C-decomposing microorganisms (that is, the heterotrophic bacteria) is promoted, while the growth of the nitric bacteria is suppressed or slowed, by which the nitrification efficiency is reduced.

10 The reduction of the organic carbon load can take place according to known processes, for example by means of the addition of flocculation agents, such as a solution of salts of multivalent metals, e.g. of iron and aluminum salts. These salts can be added to the waste water in an amount in  
15 the range of about 0.5 g/liter. In this case the colloidal carbon-containing compounds flocculate out and can be separated easily.

20 Furthermore the organic carbon load can be reduced by a preliminary biological purification with sludge separation, the separated sludge being passed into a digestion tower.

25 Further the organic carbon load can be reduced oxidatively, e.g. by treatment with ozone. In particular, this process is used in the case of dissolved carbon compounds. Further, the dissolved carbon compounds also can be removed by adsorption. This also applies to carbon compounds with substituents which can impair the subsequent  
30 nitrification, e.g. phenols and halogenated hydrocarbons.

35 Furthermore, experiments were made concerning the optimization of the  $\text{NH}_4$  nitrogen content. In this case it was found that the  $\text{NH}_4$  nitrogen content should be limited to a maximum value of about 1200, preferably about 700 mg/liter, before the nitrification. With these  $\text{NH}_4$  nitrogen

5 contents the nitric bacteria find ideal growth conditions.  
The  $\text{NH}_4$  nitrogen content can be obtained e.g. by diluting the  
waste water with clarified waste water.

10 The improvements described above (volumetric loading,  
removal of the carbon load, and limitation of the  $\text{NH}_4$   
nitrogen content) can be made individually or in  
combination.

The invention is illustrated by the following examples.

15

#### Examples

##### Example 1

20 A partial flow from the sludge treatment (200  $\text{m}^3/\text{d}$ ;  
filtrate from a chamber filter press with lime conditioning)  
with an  $\text{NH}_4\text{-N}$  content of 1040 mg/liter, a pH value of 12.5  
and a COD value of 400 mg/liter was treated with 2400 kg  
calcium bentonite from Moosburg (Terrana®, trade name of  
25 Süd-Chemie AG) (specific surface area 60  $\text{m}^2/\text{g}$ , particle size  
95% by weight < 150  $\mu\text{m}$ , cation exchange capacity 63 meq/100  
g, swelling volume 12 ml/2g, surface pH value 8.0). The  
bentonite was suspended in water (15 g/liter) and  
impregnated with nitric bacteria from activated sludge  
30 before the mixing with the waste water. The bentonite thus  
treated preliminarily was suspended in the waste water to be  
treated, and air was blown into the mixture of waste water  
and bentonite. In this case the pH value dropped gradually.  
The pH value was adjusted to  $7.0 \pm 0.2$  by adding sodium  
35 hydroxide solution via a pH-controlled dosing unit. After  
4 days at a temperature of about 20°C the  $\text{NH}_4\text{-N}$  content was

lowered to about 82 mg/liter (nitrification capacity about 92%). The nitrite N content amounted to about 815 mg/liter, the nitrate N content amounted to about 93 mg/liter. A so-called volumetric loading of about 1.3 kg  $\text{NH}_4\text{-N}$  per  $\text{m}^3$  of waste water per day results from the following equation

$$\frac{1.04 \times 200 \text{ kg}}{160 \text{ m}^3 \times \text{d}}$$

from the  $\text{NH}_4\text{-N}$  content, the basin volume, and the amount of partial flow passed through the activation basin per day.

The waste water thus treated then was denitrified in a denitrification stage ( $100 \text{ m}^3$ ) connected before the biological stage of an existing unit with external carbon dosing, whereby the nitrite / nitrate nitrogen content was reduced to  $< 1 \text{ mg/liter}$ .

### Example 2

Example 1 was repeated with the difference that the partial flow from the sludge treatment with a COD of 1200 mg/liter was treated with 0.5 g per liter of a mixture of iron and aluminum chlorides in dissolved form (Süflock K27; trade name of Süd-Chemie AG) in a preliminary sedimentation tank. The material flocculated was separated by settling, and the sludge was passed into a digestion tower. The supernatant, which had a COD value of 500 mg/liter, was passed into the activation basin of Example 1 and further treated as described in this example.

5      Example 3

Example 1 was repeated with the difference that the  $\text{NH}_4\text{-N}$  concentration amounted to 980 mg/liter and anthracite was used as carrier material (specific surface area about 30 -  
10      40  $\text{m}^2/\text{g}$ , particle size: 95% by weight < 200  $\mu\text{m}$ , surface pH value = 7.8).

The anthracite was suspended in water (15 g/l) and impregnated with nitric bacteria from activated sludge  
15      before mixing with the waste water. The anthracite thus pretreated was suspended in the waste water to be treated, and air was blown into the mixture of waste water and anthracite. In this case the pH value dropped gradually. The pH value was set to  $7.0 \pm 0.2$  by the addition of sodium  
20      hydroxide solution via a pH-controlled dosing unit.

After four days at a temperature of about  $20^\circ\text{C}$  the  $\text{NH}_4$  content was lowered to about 87 mg/liter (nitrification efficiency about 91%). The nitrite N content amounted to  
25      about 830 mg/liter, the nitrate N content to about 89mg/liter. A so-called volumetric loading of about 1.2 kg  $\text{NH}_4\text{-N}$  per  $\text{m}^3$  of waste water per day results from the following equation

30      
$$\frac{0.98 \times 200 \text{ kg}}{160 \text{ m}^3 \times \text{d}}$$

from the  $\text{NH}_4\text{-N}$  content, the basin volume, and the partial flow amounts passed through the activation basin per day.

35

The waste water thus treated then was denitrified in a

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- 5      denitrification stage (100 m<sup>3</sup>) connected before the biological stage of an existing unit with external carbon dosing, whereby the nitrite / nitrate nitrogen content was reduced to < 1 mg/liter.